Applying Advanced Leakage Control and Pressure Management
Learning Module Instructors

Reinhard Sturm
CEO – Water Systems Optimization

Julian Thornton
Thornton International

Reid Campbell
Director Water Services – Halifax Water
Learning Module Agenda

- Pressure Leakage Relationship
- Pressure Management Benefits – Failure Frequency Reduction, Lifespan Extension and Leakage Reduction
- Tools for Pressure Management
- Advanced Pressure Management Zones in Halifax
- Pressure Management Debate
Pressure and Leakage – There IS a Link
Pressure and Leakage – There IS a Link

There IS a Link

Pre-Trial

Flow Mod PRV

Fixed PRV

Main Breaks

Service Breaks

No. Breaks

Pressure and Leakage – There IS a Link
Pressure Fluctuations and Transients
Predicting Relationship Between Pressure and Leakage

Fixed Area and Variable Area Discharges (FAVAD)

Leakage rate $L$ varies with Pressure $P^{N_1}$
where $N_1$ may vary between 0.5 and 2.5
Pressure Control Expands After 1995

- Thousands of pressure control schemes installed internationally since 1995 to reduce leakage; justified economically due to:
  - better methods to predict reductions in leak flow rates (FAVAD, simplified to N1 Power Law)
  - advanced pressure control with flow modulation
  - methods to predict reductions in new burst frequency on mains, and services, and extend infrastructure life

- As a consequence many systems now are operating at lower and more variable pressures

- It has now became necessary to review concepts used for calculations – moving from N1 to use FAVAD concept where necessary
Recent Collaborative Research on FAVAD

• By Prof. Kobus van Zyl, Allan Lambert, Dr Richard Collins and post-grad University of Cape Town students
  • Leakage Numbers for lab tests on pipe samples:
  • Leak Area vs pressure relationships
  • Influence of low/negative pressure on leak flow rates

• Open Access paper on hydraulic analysis by van Zyl, Lambert and Collins ASCE Journal of Hydraulic Engineering / Vol 143 Issue 9 - Sept 2017 (1000+ downloads)
  • summarised in Presentation 2017S on LEAKSSuite

• Allan Lambert has now applied FAVAD concepts to N1 tests, to get fast-track methods for practitioners to use
  • See http://www.leakssuite.com/favad-and-n1update/
Fast Track Approaches for Practitioners

• Use Fast-track FAVAD calculations, customised for practitioners, for improved leakage calculations

• WLR&A’s ‘Leakage Practitioner’ fast-track approach for Utilities using FAVAD in 6 steps:
  1. Calculate N1 from an N1 test, or assume N1, at a specified Average Zone Pressure
  2. Identify % split of Fixed and Variable Area leaks from N1
  3. Then calculate N1 vs Average Zone Pressure equation
  4. Use N1 test to define Leak Flow Rate vs AZP equation
  5. Predict zonal leakage from AZP pressures in real time
  6. Improve reliability of assessment of Night-Day Factors
Fast Track Approaches for Practitioners

**Step 3:**
Derive N1 vs AZP equation and graphs from N1 test data

**Step 4:**
Derive L vs AZP equation and graphs from N1 test data

**Step 5:**
Use AZP and L vs AZP equation to track leak flow rates in real time

**Step 6:**
Use AZPave and AZPmnf and N1 at AZPave to calculate Night-Day Factor NDF

http://www.leakssuite.com/favad-and-n1update/

http://www.leakssuite.com/night-day-factor-update/
Pressure Leakage Relationship

• Large leaks from metal pipes \( - N1 \sim 0.5 \)
• Background Leakage \( - N1 \sim 1.5 \)
• Entire Systems with mixed pipe \( - N1 \sim 1 \)
Pressure Leakage Relationship

Graph showing the ratio of leakage rates $L_1/L_0$ as a function of the ratio of pressures $P_1/P_0$. The graph includes different markers for different values of $N_1$: $N_1 = 0.50$, $N_1 = 1.00$, $N_1 = 1.15$, $N_1 = 1.50$, and $N_1 = 2.50$. The x-axis represents the ratio of pressures $P_1/P_0$ and the y-axis represents the ratio of leakage rates $L_1/L_0$. The graph shows an increasing trend as $P_1/P_0$ increases for all values of $N_1$. 
At pressure $P_0 (= 71 \text{psi})$, the leakage rate $L_0 = 10.0 \text{ gpm}$.

What is the predicted leakage rate at pressure $P_1 = 50 \text{ psi}$, for various $N_1$ values?

Use the equation $L_1 = L_0 \times \left( \frac{P_1}{P_0} \right)^{N_1}$

- If $N_1 = 0.5$, $L_1 = 10 \times \left( \frac{50}{71} \right)^{0.5} = 8.4 \text{ Gpm}$
- If $N_1 = 1.0$, $L_1 = 10 \times \left( \frac{50}{71} \right)^{1.0} = 7.0 \text{ Gpm}$
- If $N_1 = 1.5$, $L_1 = 10 \times \left( \frac{50}{71} \right)^{1.5} = 5.9 \text{ Gpm}$
- If $N_1 = 2.5$, $L_1 = 10 \times \left( \frac{50}{71} \right)^{2.5} = 4.1 \text{ Gpm}$
# Pressure Leakage Relationship

<table>
<thead>
<tr>
<th>Pressure Management Opportunities</th>
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</thead>
<tbody>
<tr>
<td><strong>Existing Pressure Management Policy</strong></td>
</tr>
<tr>
<td>Current Average System Pressure</td>
</tr>
<tr>
<td>Total Annual Real Losses</td>
</tr>
<tr>
<td>Value of Real Losses</td>
</tr>
</tbody>
</table>

FAVAD N1 Value Used for Calculation of Real Loss Reduction Due to Reduction of Average System Pressure:
- Use Default N1: 1.0
- Use System Specific N1: 0.7

Enter % of rigid pipes and service connections in system: 100%

<table>
<thead>
<tr>
<th>Alternative Pressure Management Policy</th>
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</thead>
<tbody>
<tr>
<td>Assumed Reduction in Average System Pressure</td>
</tr>
<tr>
<td>Assumed % Reduction in Average System Pressure</td>
</tr>
<tr>
<td>Real Loss Volume Saved Through Alternative Pressure Management Policy</td>
</tr>
<tr>
<td>Value of Real Loss Volume Saved Through Alternative Pressure Management Policy</td>
</tr>
</tbody>
</table>

Enter Estimated Cost of Implementing Alternative Pressure Management Policy: 100,000 $

Simple Payback Period for Implementing Alternative Pressure Management Policy: 1.5 Years
# Pressure Management Benefits

### Pressure Management: Reduction of Excess Average and Maximum Pressures

<table>
<thead>
<tr>
<th>Conservation Benefits</th>
<th>Water Utility Benefits</th>
<th>Customer Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Flow-rates</td>
<td>Reduced Frequency of Burst and Leaks</td>
<td>Fewer Customer Complaints</td>
</tr>
<tr>
<td>Reduced Consumption</td>
<td>Reduced Repair Costs, Mains &amp; Services</td>
<td>Fewer Problems on Customer Plumbing &amp; Appliances</td>
</tr>
<tr>
<td>Reduced Flow Rates of Leaks and Bursts</td>
<td>Deferred Renewals and Extended Asset Life</td>
<td></td>
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</tbody>
</table>
Pressure Management Benefits

**Background Leakage**
Unreported and un-detectable using traditional acoustic equipment.

Tools
- Pressure Reduction
- Main and service replacement
- Reduction in the number of joints and fittings

**Unreported Leakage**
Often does not surface but is detectable using traditional acoustic equipment.

Tools
- Pressure Reduction
- Main and service replacement
- Reduction in the number of joints and fittings
- Proactive Leak Detection

**Reported Leakage**
Often surfaces and is reported by public or utility workers.

Tools
- Pressure Reduction
- Main and service replacement
- Optimized repair time
Failure Frequency Reduction
And Lifespan Extension
Predicting Reduction in Breaks by Reducing Pmax

- This approach links the ‘straw that breaks the camel’s back’ concept to the ‘Slope S’ predictions
  - and explains why Slope S in PMZs varies between 0 and around 3.0
Consider the situation when new mains and services are laid, they are designed to withstand existing system pressures with a large factor of safety, so failure rate is low.
If the new pipe system experiences pressure transients or variations the factor of safety is reduced, but the failure rate may remain quite low.
Pipes deteriorate through age and corrosion, and other local and seasonal factors reduce the ‘failure’ pressure until eventually burst frequency starts to increase significantly, often on a seasonal basis.
The first step in pressure management is to check for the presence of pressure transients or variations; if they exist, reduce the range and frequency of both.
Next, identify if the stabilized pressures at the critical point are higher than necessary; if so, reduce the excess to avoid operating system at its ‘failure’ pressure.
Over time the age and corrosion factors grow and reduce the safety factor throughout the year. Infrastructure replacement has to take place eventually, however in many cases significant benefits have been gained by deferring the investment through management of previously excess pressures.
If the current failure rate is comparatively high (red circle), then quite a small % reduction in pressure (to the blue circle) may produce a large reduction in failure frequency. But if the failure frequency is already quite low (blue circle), further pressure reductions may not greatly reduce the current failure frequency, but could extend infrastructure life.
Reduction of excess pressure reduced the average mains failure frequency AND the large range of seasonal failure frequencies, so that even peak seasonal failures were within acceptable limits, giving many years extra life. The improved 2011 visual explanation (next slide) shows why!
Average annual failure frequency consists of non-pressure dependent failures (BFnpd) plus failures triggered by excess pressure when added to other seasonally varying environmental factors.
A North American city main break/leak seasonal trend changes when finished water temperature changes abruptly.
Example BFnpd – Ground Movement

ARE THERE EARTHQUAKES IN CANADA?
Example BFnpd Third Party Hits
Example BFpd Tank Overflows
Example BFpd Pipe Leakage
What to Expect?

Source: Gold Coast Australia
Pressure Management and Infrastructure Life Span
One bucket full obviously has to go! One is OK – not sure about the other… perhaps pressure management can extend the life
Factors Contributing to Asset Life and Control Measures

Factors
• Soil Load
• Live Load
• Thermal Stress
• Risk
• Ground Movement
• 3rd Party Digging
• Degradation Rate
• Operating Pressure
• Surge Pressure

Control measures
• Remove soil cover
• Divert traffic
• Manage water / ground temperature
• Move pipe
• Better trenches
• Call before you dig program
• Corrosion control
• Pressure Management
• Pressure Management
• Average life of AC pipes before failure by lateral splits increases as maximum pressure decreases

<table>
<thead>
<tr>
<th>AC Pipe DN/Class</th>
<th>Maximum Pressure (metres)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
</tr>
<tr>
<td>100/CD</td>
<td>55</td>
</tr>
<tr>
<td>150/C</td>
<td>60</td>
</tr>
<tr>
<td>200/C</td>
<td>72</td>
</tr>
<tr>
<td>250/C</td>
<td>82</td>
</tr>
<tr>
<td>300/C</td>
<td>95</td>
</tr>
</tbody>
</table>

• Reductions in maximum pressure can add several years to average life of AC mains
  – depending upon the reduction in maximum pressure, and the pipe diameter, Class and wall thickness

• Zones with large amounts of AC mains having low residual life can be targeted for pressure management
  – and financial benefit of deferred replacement calculated

Source: John R Black
Each utility should:

- Verify surge pressures
- Smooth where possible
- Verify operating pressures
- Look for opportunities to manage pressure
- Reduce OPEX to an efficient level
- Identify pipe nearing end of useful life
- Increase the useful life of the pipe if possible
- Focus CAPEX on unavoidable replacements
Tools For Pressure Management
Pressure Reduction
Flow Modulated Control

Remote Node Modulation
Remote Note Modulated Control
Pump Control
Halifax Water’s Experience With Pressure Management
Water Loss Control at Halifax Water

• Adopted IWA/AWWA Methodology in 2000.
• Reduced ILI from 9.0 to 2.4
• System Inputs reduced from 168 to 130 MLD.
• 45 pressure zones, 75 DMA’s, 1 PMA
Dartmouth Central PMA

- Flow modulated pressure control
- Controller reduces system pressure as demands decrease
Dartmouth Central PMA: Before and After

Avg Annual 2002/03 – 2004/05

Main Leaks = 23
Pub. Service Leaks = 4
Priv. Service Leaks = 5

2005/2006

Main Leaks = 12
Pub. Service Leaks = 2
Priv. Service Leaks = 3

Since 2005/2006: 16 /year
Pressure Management at Halifax Water

• Based on several years of flow modulated pressure control:
  • Breaks are measurably reduced
  • Dependent on system characteristics
• At the time thought that it had important but limited application across the utility
• Dartmouth Central PMA/DMA has operated since 2005-06.
  • Changed to solenoid control in 2013-14
• Based on recent data analysis opportunity for pressure management is much greater
Collins Park is a small system owned by Halifax Water:
- Commissioned 1988
- Average system pressure: 70 psi
- 75 residential customers
- Ductile iron distribution system (2 km’s)
- Direct pressure provided by pumps at the WTP
- No specific break/leak history

In response to new Provincial Water Treatment standards, a new treatment plant was constructed
- Commissioned in June 2010
Collins Park System

• 5 breaks in two months after commissioning:
  • Pressure increased by 15 psi
  • Pressure surges detected by logging
  • Quality of repairs
Proactive Pressure Reduction

- Pressure reduced slightly in some zones
  - 6 zones with reduced pressure
  - 2-5 psi reduction
In 2012 we did a statistical analysis of all watermain breaks

Key findings:
- 60% of all breaks happen between midnight and 6 am
- Similar occurrence for all break types
- Break clusters

New Finding
Where Are We Going Next?
Breaks vs Time of Day

![Bar chart showing percentage of leaks by time of day: 00:00 to 6:00 has the highest percentage, followed by 6:00 to 12:00, then 12:00 to 18:00, and finally 18:00 to 00:00.](image)
Pressure spikes in the distribution system captured on SCADA as reservoir altitude valve closes too quickly.

Main failure correlates to pressure spikes.
New Strategies

• Night time pressure creep in PRV fed zones
  • PRV’s less precise in low end of flow range
  • Due to water loss control:
    • PRV’s night time operation in lower end of design range
    • Less leakage to provide base line flow through prv
    • Less leakage to dampen HGL
  • Need for improved maintenance

• Analysis of individual breaks will identify high priority prv’s for maintenance or re-configuration
During low night flows, system pressure creeps up 60 kpa as a result of a malfunctioning PRV.
• On August 20, 2015, we had 6 breaks in a single zone over a 6 hour period
Series of Water Main Breaks in the Bedford Low Zone - August 20, 2015
Questions or Comments?
Lets talk about it